

Techno-Economic Assessment of an Integrated VRV Heat Pump, Gas Condensing Heating and 72 kWp Photovoltaic System: A Case Study



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ICIA – Institut de Cercetari si Amenajari Silvice • Cluj-Napoca, Romania • Climate Zone III (Te = -18°C, 2,765 DD)

Post-renovation: 753 MWh/yr heating demand | Gas: 56.73 EUR/MWh | Elec: 221.1 EUR/MWh | PV: 73.6 kWp, ~39 MWh/yr | 1 EUR = 5.2649 RON (BNR 21.09.2026)

Vitodens 200-W
2x80 kW Cascade

Daikin VRV 5S
7 Outdoor Units

Hybrid Bivalent
Point -7 degC

PV 73.6 kWp
Huawei SUN2000

Cluj-Napoca
Climate Zone III • 2,765 DD

VARIANT 1 – GAS ONLY

768.4 MWh/yr
34.9k EUR/yr
155 tCO2/yr
eta = 98%

Gas Input Heating Cost (net PV) CO2 Emissions Boiler Efficiency

VARIANT 2 – VRV + PV

179.3 MWh gross
31k EUR/yr
52.5 tCO2/yr
COP = 4.2

Electricity (VRV) Cost after PV CO2 Emissions Heat Pump COP

VARIANT 3 – HYBRID + PV

136.3+82.1 MWh
26.2k EUR/yr
56.6 tCO2/yr
COP_eff = 3.45

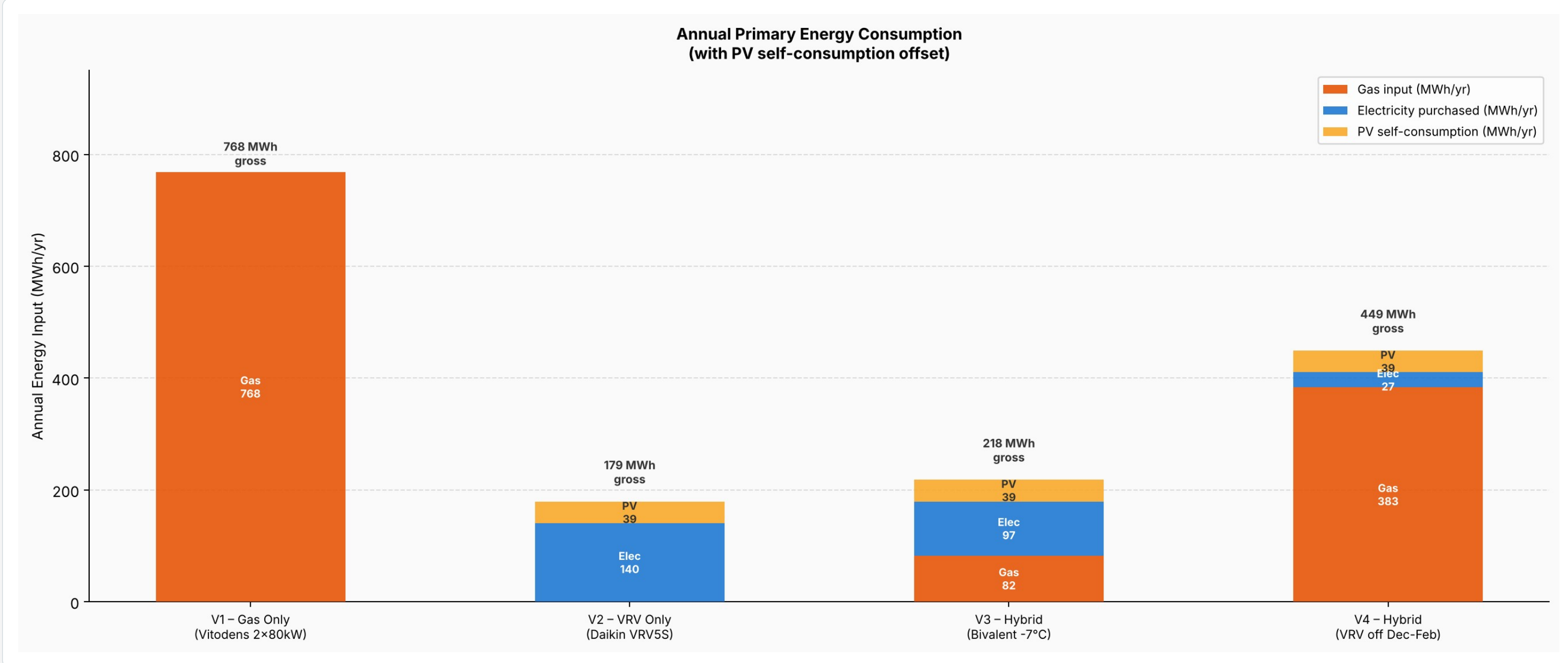
Elec + Gas Input Cost after PV CO2 Emissions System COP

VARIANT 4 – VRV OFF DEC-FEB

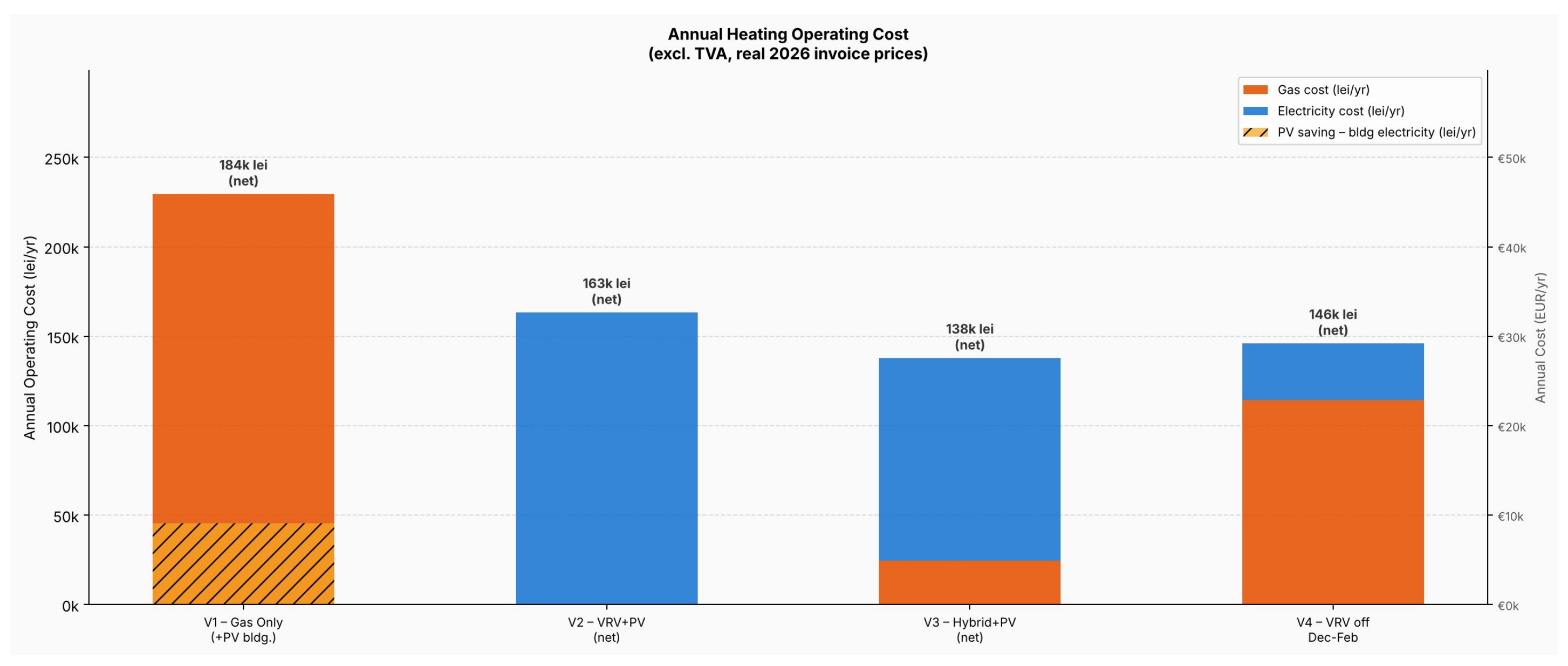
66.1+383.2 MWh
27.7k EUR/yr
96.8 tCO2/yr
COP_eff = 1.68

Elec + Gas Input Cost after PV CO2 Emissions System COP

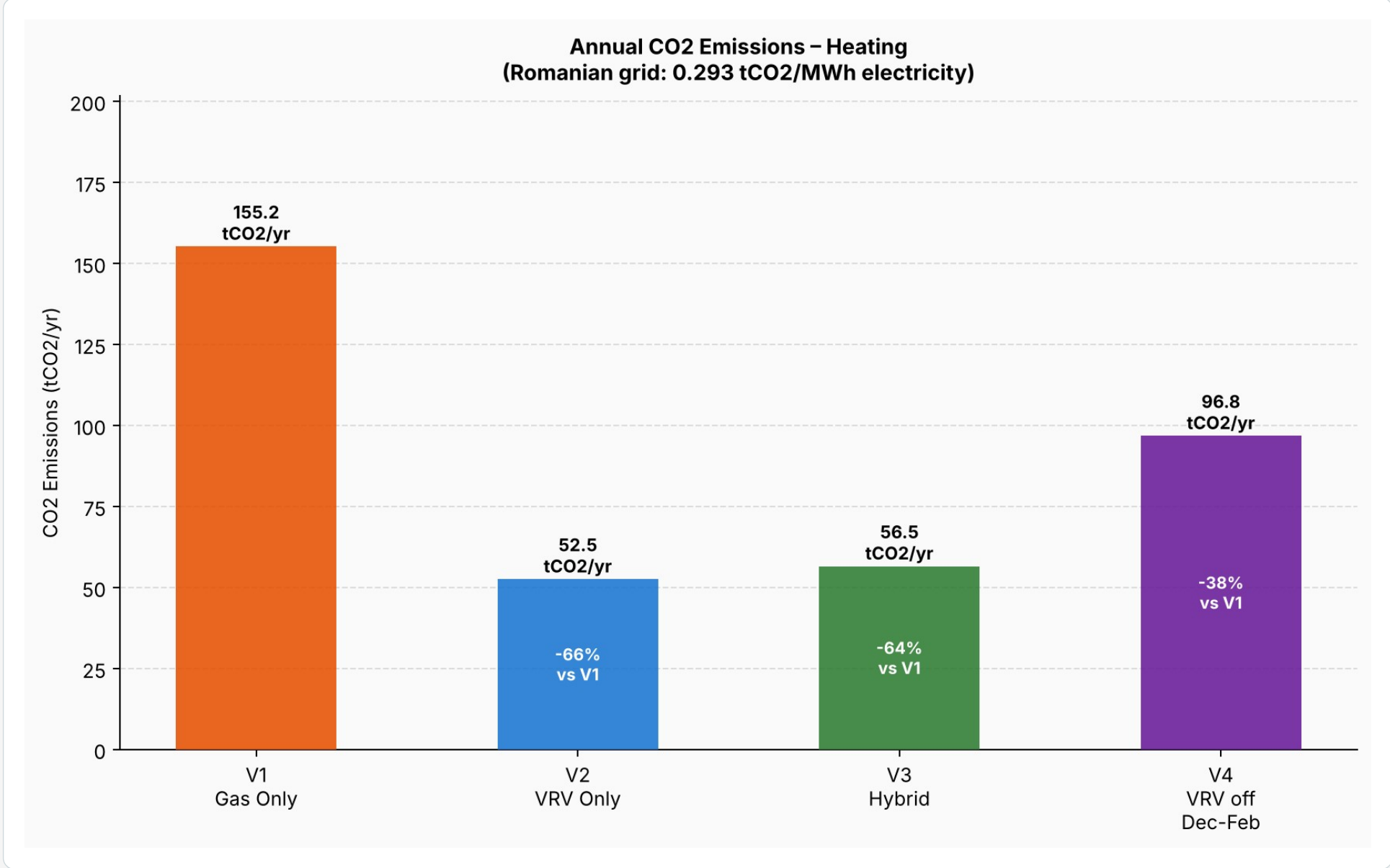
1. Primary Energy by Variant (with PV offset)



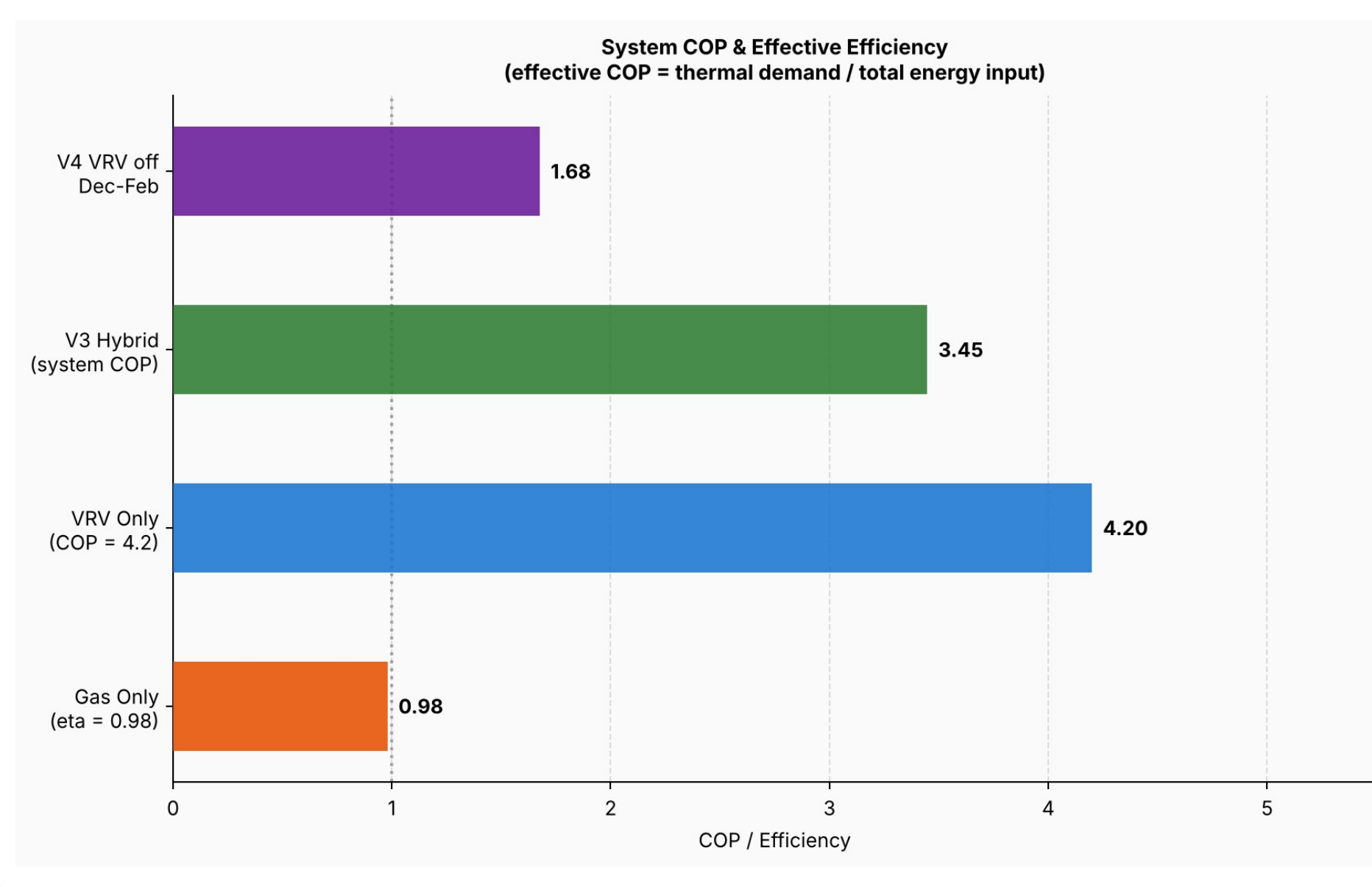
2. Annual Operating Cost – 2026 Real Prices



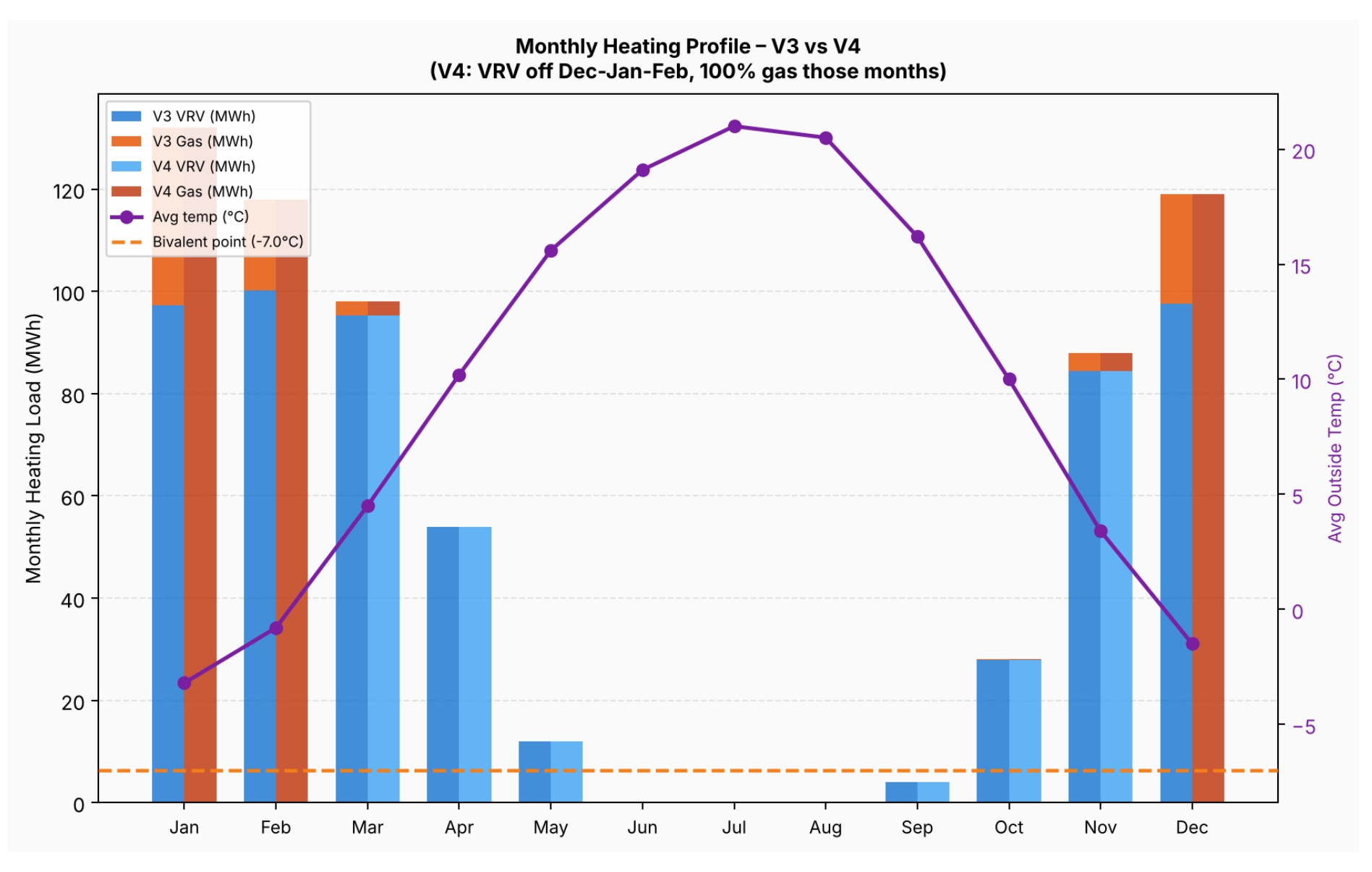
3. CO2 Emissions



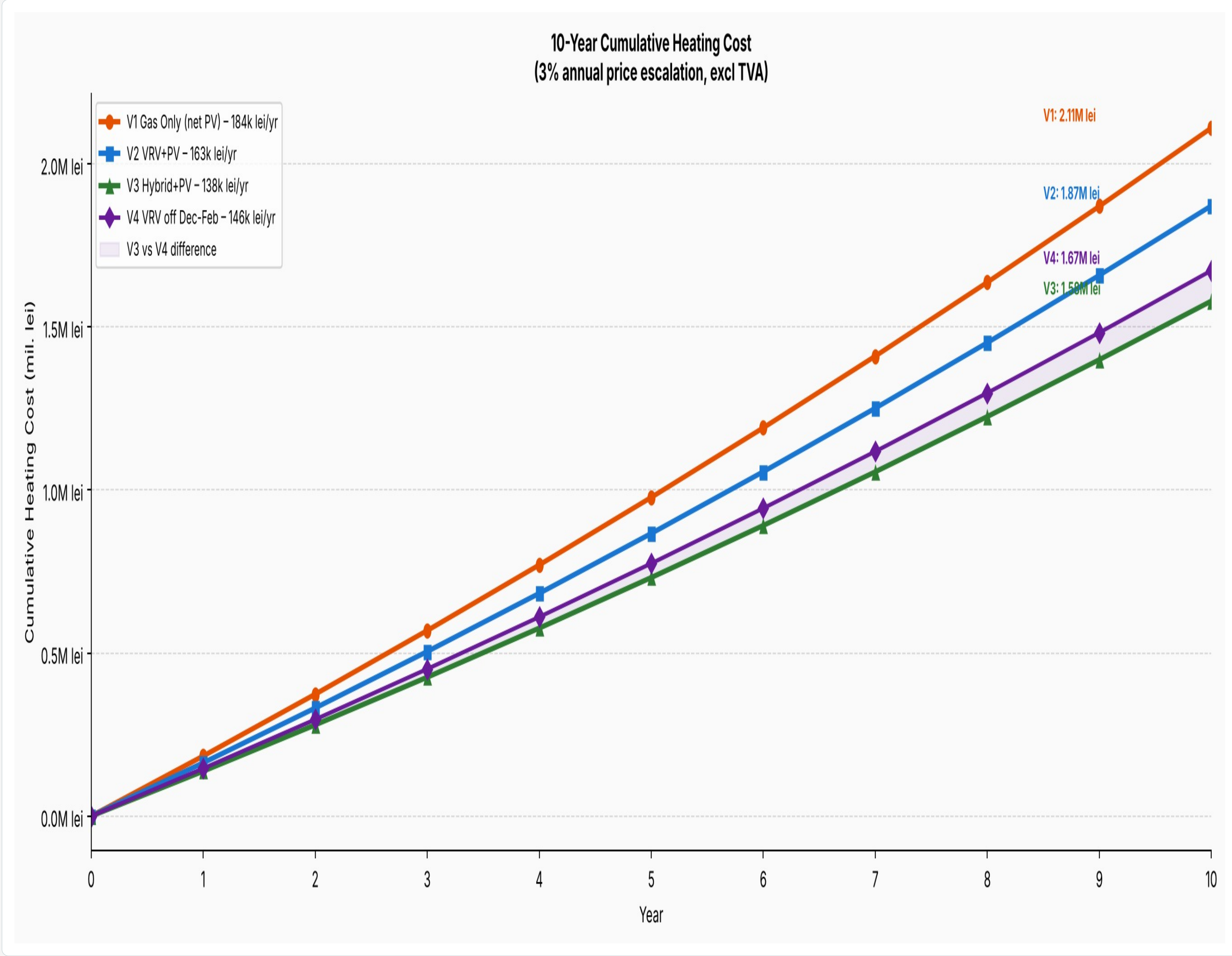
4. COP & System Efficiency



5. Monthly Bivalent Profile V3 vs V4



6. 10-Year Cumulative Cost (3% escalation, excl TVA)



7. Comparative Summary Table

Parameter	V1 Gas Only	V2 VRV+PV	V3 Hybrid+PV	V4 VRV off Dec-Feb
Technology	Vitodens 200-W 2x80kW	Daikin VRV 5S 7 units	VRV+Gas cascade bivalent -7°C	Hybrid: VRV off Dec-Jan-Feb
Gas price (2026)	56.73 EUR/MWh	—	56.73 EUR/MWh	56.73 EUR/MWh
Elec price (2026)	221.1 EUR/MWh	221.1 EUR/MWh	221.1 EUR/MWh	221.1 EUR/MWh
Gas input (MWh/yr)	768.4	0	82.1	383.2
Elec gross (MWh/yr)	0	179.3	136.3	66.1
PV offset (MWh/yr)	39 (bldg)	39	39	39
Net elec (MWh/yr)	0	140.3	97.3	27.1
Annual cost (lei/yr)	184k	163k	138k	146k
Annual cost (EUR/yr)	34.9k EUR	31k EUR	26.2k EUR	27.7k EUR
CO2 (tCO2/yr)	155.2	52.5	56.6	96.8
COP / Efficiency	eta=0.98	COP=4.20	COP_eff=3.45	COP_eff=1.68
VRV / Gas split	—	100% VRV	76% VRV / 11% gas	42% VRV / 58% gas
VRV months active	—	12 months	T>-7°C bivalent	Mar-Nov only (9 months)
Real gas Nov25-Apr26	—	—	166.3 MWh measured	—

8. Conclusions & Recommendations

Variant 1 – Gas Only (Vitodens 200-W, 2x80kW, eta=98%): 34.9k EUR/yr net (after PV building offset)

At real 2026 prices (56.73 EUR/MWh gas), gas heating is ~8.7k EUR/yr MORE expensive than the hybrid system. PV generates 39 MWh/yr saving ~8.4k EUR/yr on general building electricity. Highest CO2: 155 tCO2/yr.

Variant 2 – VRV Only + PV (Daikin VRV 5S, COP=4.2): 31k EUR/yr (net electricity after PV offset)

Lowest CO2: 52.5 tCO2/yr (-66% vs gas). At design temperature Te=-18°C, VRV COP drops to ~1.8; heating capacity must be verified for extreme cold without gas backup. PV offsets 39 MWh of 179 MWh gross consumption.

Variant 3 – Hybrid Bivalent + PV (installed system, bivalent -7°C): 26.2k EUR/yr – RECOMMENDED

Optimal balance: VRV covers 76% of thermal demand (T>-7°C); gas cascade activates for remaining 11% including extreme cold (Dec-Feb, T reaches Te=-18°C). VRV OFF below -7°C prevents efficiency collapse. Real gas meter Nov25-Apr26: 166.3 MWh confirms model. CO2: 57 tCO2/yr. Effective COP = 3.45.

Variant 4 – VRV OFF Dec-Jan-Feb (9 active months): 27.7k EUR/yr – conservative winter scenario

Forcing gas-only operation Dec-Jan-Feb (3 coldest months) raises gas input to 383.2 MWh/yr and reduces VRV electricity to 66.1 MWh/yr. CO2 rises to 96.8 tCO2/yr (+71% vs V3). Annual cost 27.7k EUR/yr – only 6% above V3 due to lower electricity tariff for winter gas. System COP_eff = 1.68 (vs 3.45 for V3). Not recommended unless VRV reliability in winter is a concern.